TEMS™ CellPlanner

LTE Technical Reference Manual

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Preface

Document Conventions

This document uses the following conventions:

Bold type	Window names, button names, and keyboard keys are displayed as bold text. Example: Click **Edit.**
Menu↗Selection	Navigation in menu paths are displayed as bold text with arrows between menu levels.
`Typewriter type`	File names and literal input and output. Example: `sites.xml`
Italic type	Book titles and definitions are displayed in italic. Examples: *carrier mapping, Technical Reference Manual*
Left-click Right-click	All instructions including mouse clicks assume a mouse configured with the left mouse button as primary button.

Navigation

Use the ALT ← and ALT → buttons to navigate between link jumps in the Manuals.

Assumed Knowledge

This documentation presumes that you have good knowledge about radio network planning principles and the radio technology to plan.

Disclaimer

The parameter values in this manual are just examples to help you getting started quickly, and do not constitute any performance guarantees for the planned equipment of your final network planning.

Proper parameter values depend on the equipment version, the operator's business plan, and the operator's network deployment strategy. Recommended parameter values should be provided by the operator, the equipment vendor or your service delivery organization.

Manuals

The following PDF manuals are delivered with the TEMS CellPlanner software:

Installation Guide

EN/LZT 108 9831 R4A

Describes system requirements, how to install and configure TEMS CellPlanner components and manage licenses, and provides an overview of all TEMS CellPlanner components. The procedures must be performed by a user with administrator privileges on the local computer. Some procedures require that you are an authorized TEMS CellPlanner administrator.

Common Features User's Guide

EN/LZT 108 9832 R4A

Includes Glossary of terms used in TEMS CellPlanner, concepts about licenses, and how use projects, explorer objects used by more than one radio technology, how to add sites and use site tools, filters, plots, neighbors, AMI, tuning propagation models, ASMT (Automatic Sector Model Tuning), puncturing, export and import data, and work with projects on server. Here TEMS CellPlanner administrators find how to administer users, groups and projects on servers shared by multiple users.

Common Features Technical Reference Manual

EN/LZT 108 9833 R4A

Describes radio technology independent algorithms, parameters and file formats.

GeoData User's Guide

EN/LZT 108 9834 R4A

Describes geodata concepts, supported geodata formats, conversion between different map formats, how to use map data tools in TEMS CellPlanner. The chapters about providing and importing map data are intended for administrators of map data. Other chapters are intended for users of map data.

Map Import Wizard User's Guide

EN/LZT 108 9943 R2A

Describes how to import map data using a generic wizard similar to the one provided with TEMS LinkPlanner. The intended reader is administrator of map data.

LTE User's Guide

EN/LZT 108 9944 R3A

Describes how to use LTE functions of TEMS CellPlanner, including analysis, and creation of plots and reports.

LTE Technical Reference Manual

EN/LZT 138 0235 R2A

Describes LTE network planning principles, analysis details for advanced users, and cell ID planning principles.

WCDMA User's Guide

EN/LZT 108 9837 R4A

How to use WCDMA functions of TEMS CellPlanner, including analysis, and creation of plots and reports.

WCDMA Technical Reference Manual

EN/LZT 108 9838 R4A

Describes concepts and overviews of WCDMA algorithms, and HSPA and MBMS in TEMS CellPlanner.

GSM User's Guide

EN/LZT 108 9835 R4A

Describes how to use the GSM functions of TEMS CellPlanner, including analysis, and creation of plots and reports.

GSM Technical Reference Manual

EN/LZT 108 9836 R4A

Describes overlaid/underlaid cell structures, reuse patterns, manual frequency planning, automatic frequency planning (AFP), automatic hopping frequency set (HFS) planning, optimization of BSIC, HSN and MAIO, fractional load planning, and effective subscriber modeling. Also describes the GSM algorithms and file formats used in TEMS CellPlanner.

WiMAX User's Guide

EN/LZT 108 9839 R4A

Describes how to use the WiMAX functions of TEMS CellPlanner, including analysis, and creation of plots and reports.

1
Overview of TEMS CellPlanner

This chapter provides an overview of the TEMS CellPlanner product.

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About TEMS CellPlanner

TEMS™ CellPlanner is a graphical PC-based application for designing, implementing, and optimizing mobile radio networks. It assists you in performing complex tasks, including network dimensioning, traffic planning, site configuration, frequency planning, and network optimization.

Installation

The Installation Guide describes how to install software and licenses.

Product Packaging

The product package includes the software components listed below.

What is actually installed depends on your selection in the installation wizard.

Product Components	Selecting this component installs...
• TEMS CellPlanner *named "TEMS CellPlanner Client" in the manuals*	• Radio Technology Features • Planning Features • Manuals • Map tools, geodata conversion software, demo maps, filters, scripts • Citrix software - relevant only if you are going to offer this TEMS CellPlanner installation as a Citrix service
• Enterprise Server	Enterprise Server software plus the User Administration software
• Zero Admin Server	Zero Admin Server software plus the User Administration software
• User Administration	User Administration software only
• License Server	License Server software only

Some of the components are licensed, see Licensed Components on page 1-3.

The Installation Guide provides an overview of each component and how the components relate to each other.

Licenses

The Installation Guide describes how to install licenses.
The Common Features User's Guide describes how to activate licensed features.

Licensed Components

Three of the Product Components are licensed:

TEMS CellPlanner *named "TEMS CellPlanner Client" in the manuals*	To start TEMS CellPlanner you need a license for at least one of the Radio Technology Features. Additional licenses are required for each of the Radio Technology Features and Planning Features to use.
Enterprise Server	License required to start the server
Zero Admin Server	License required to start the server

Radio Technology Features

Each of the radio technology software modules listed below require an installed and activated license. How to use the radio technology software is described in adherent user guides and technical reference manuals.

- GSM
- WCDMA
- WCDMA,HSPA
- WiMAX
- LTE

Planning Features

Additional planning features can be used together with the radio technology software. These additional software modules require a license for the feature itself and a license for the adherent radio technology:

• Automatic Cell Planning	Requires WCDMA or WCDMA,HSPA license
• Automatic Frequency Planning	Requires GSM license. This license is required also for automatic HFS planning.
• Automatic Measurement Integration and ASMT	Requires license for at least one of the Radio Technology Features ASMT = Automatic Sector Model Tuning.

Support and FAQ

For support and FAQ about TEMS CellPlanner, use the TEMS support web site:

www.ascom.com/networktesting

To provide TEMS support with information when reporting a problem, follow the instructions in chapter *Support Information* in the Installation Guide.

2
LTE Network Planning Principles

This chapter provides an overview of LTE air interface properties and their influence on network planning principles applied in TEMS CellPlanner. In this document it is assumed that the reader has a general knowledge on the LTE air interface.

Information on handling of fixed subscribers in the LTE Analysis is also described here. Current limitations in LTE network planning are summarized in the last section.

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2.1 LTE Air interface Modeling in TEMS CellPlanner

The LTE analysis functions in TEMS CellPlanner allow you planning of an LTE network based on geographical data, analyzing the network plan and presenting analysis results in plots and reports.

The air interface properties of LTE influence to a large extent the way an LTE network is simulated and analyzed in planning tools like TEMS CellPlanner.The following chapters provide an overview on these planning principles.

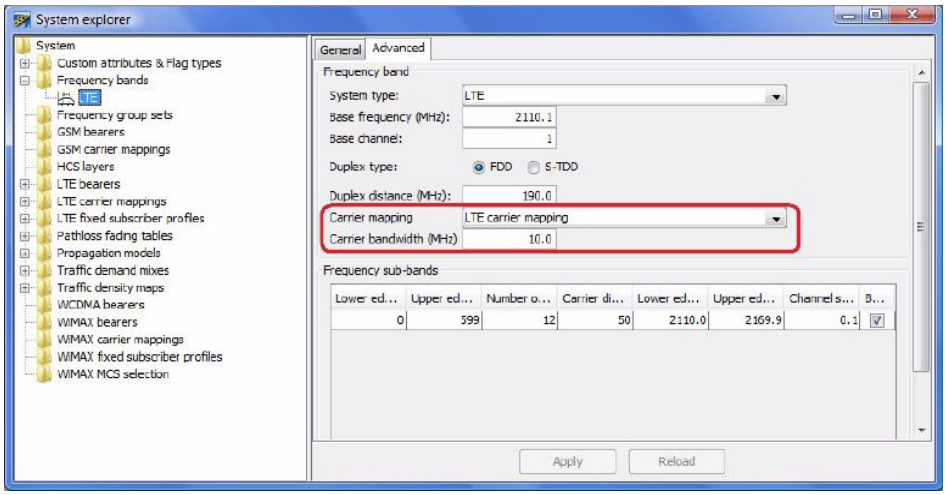
2.1.1 LTE Spectrum Flexibility

The LTE air interface is designed for high spectrum flexibility and capabilities of using a wide variety of different spectrum allocations. The LTE standard is based on a frequency allocation technique called Orthogonal Frequency Division Multiplexing - OFDM, which allows the use of a number of narrow-band channels for UL and DL transmissions. The frequency separation between these channels is chosen such that the different channels do not interfere with each other, even if used in adjacent order. Therefore, the channels are orthogonal to each other and there is no need for frequency planning in LTE as was done for e.g. GSM.

Unlike in WCDMA, where orthogonality between the different channels is achieved by orthogonal channelization codes, LTE provides orthogonality already in the radio frequency channel allocation. As a consequence, there is no code or power planning required in the same manner as for e.g. in WCDMA.

Furthermore, the amount of sub-channels that can be allocated to UL and DL transmissions can be varied so that different spectrum bandwidths can be deployed, reaching from 1.4 MHz to 20 MHz.

In TEMS CellPlanner you can plan any LTE frequency band and spectrum bandwidth. The corresponding settings are done in the LTE Frequency Band editor.



2.2 LTE Multi-user Access and Channel Structure

The LTE air interface provides means for multiple users to access the system independently in UL and DL transmission. The corresponding access schemes are called Orthogonal Frequency Division Multiple Access (OFDMA) in DL and Single Carrier Frequency Division Multiple Access (SC-FDMA) in UL.

The main property of these access schemes is that multiple users can share parts of the assigned spectrum at the same time but on different sub-channels of the assigned LTE frequency band.

The channel structure of LTE is designed in such a way that the channels are provided in the time domain as time slots, and in the frequency domain as a number of sub-channels (time/frequency matrix) over which the information is sent. The basic air interface resource in LTE is called a Resource Block (RB). It consists of 12 sub-carriers of 15 kHz bandwidth each (sums up to 180 kHz) in a time slot of 0.5 ms. As the scheduler allocates radio resources on a 1 ms sub frame basis (2 time slots) the TTI of the LTE air interface is 1 ms.

Based on the radio conditions in terms of signal quality, on the transmission schemes supported by the LTE network equipment (eNodeB) and on the terminal capabilities the scheduler will assign a certain number of RBs to each of the terminals connected to a cell. The resource allocation is in that way mainly controlled by the scheduling function in the eNodeB. There is no channel switching in LTE as was the case for e.g. WCDMA.

For capacity planning this is an important advantage as the available cell capacity in UL and DL is provided in number of RBs. Each RB is able to carry a certain amount of data on the physical layer, Layer 1. The actual amount of data carried is depending on the signal quality of the UL and DL and on the Modulation and Coding Scheme (MCS) supported by the cells and by the terminals.

For network planning the achievable data rates are calculated for Layer 1 only. They are retrieved from so-called *data rate mapping tables*, which provide measured data rates per RB for different transmission schemes, multiplexing and coding schemes, terminal types and signal quality parameters (Signal to interference plus noise ratio C/(I+N)) as well as for different radio channel models.

In the current implementation of TEMS CellPlanner these data rate mapping tables are hard-coded and cannot be edited by the user. The main reason is the complexity of these tables and the fact that there are no large-scale deployments and measurements of real LTE performance available yet. As more vendor independent measured data rates become available these tables will be updated and will also be available for user-defined parameter settings.

2.3 LTE Transmission Schemes

Already in WCDMA/HSPA higher order modulation schemes were applied to increase the spectrum efficiency of the air interface. The more modulation and coding schemes that are available for the link adaptation algorithms, the more flexible the radio interface can be controlled in terms of achievable bit rate under varying radio conditions. Especially for users in good radio conditions the use of higher order modulation and less complex coding schemes leads to a higher data rate and higher spectrum efficiency of the transmission.

In addition to the modulation and coding schemes, several transmit and/or receive paths can be used in the air interface to increase the amount of information that can be transported over a physical radio channel. Depending on the antenna configuration and on the capabilities of terminals and eNodeB cells, advanced transmission schemes can be applied.

For LTE the use of multiple antennas at both the base station and the terminal side has been standardized. Such configuration allows the application of diversity transmission, diversity reception and spatial multiplexing using MIMO.

Using spatial multiplexing and advanced signal processing in both the transmitters and receivers, the data stream can be split into several layers, with each layer transporting the same amount of physical data. This way, the data rate for the user can be increased up to four times for 4 Tx and 4 Rx antennas and the spectrum efficiency increases up to four times as well.

Currently the TEMS CellPlanner LTE Analysis supports the following transmission schemes:

Transmission scheme	Used in	Description
1x2 MRC, also called SIMO	DL and UL	Single transmit antenna at the eNodeB and receiver diversity at the terminal
2x2 Tx diversity	DL	Two transmit antennas with transmit diversity at the eNodeB and receiver diversity at the terminal
2x2 Tx diversity combined with 2x2 MIMO	DL	Two transmit antennas at the eNodeB with transmission of separate data streams on each antenna and corresponding spatial multiplexing at the terminal side

The choice of transmission scheme during network planning of an LTE system depends on the achieved signal quality of the best serving cell for each position covered by the network. The LTE Analysis algorithm calculates the achieved C/(I+N) for the best server coverage area of all cells and evaluates the best possible transmission scheme to be applied for data rate calculations. The corresponding data rate tables are then selected from the terminal capabilities. The DL transmission scheme and rank are provided in the DL Transmission Scheme Plot (as described in the *TEMS CellPlanner LTE User's Guide*) after the LTE Analysis has been done successfully.

2.4 Radio Channel Models for LTE

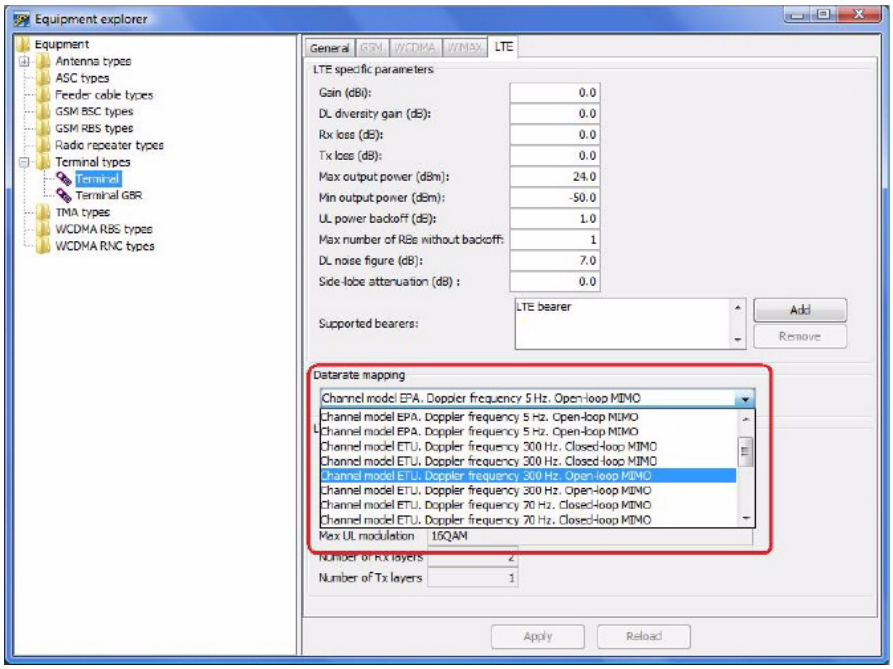
One important parameter for simulation of the radio interface in LTE is the actual radio channel bandwidth that is used for LTE data transmissions. The radio channel of LTE can cover up to 20 MHz of radio signal bandwidth, which is four times as much as WCDMA uses. Consequently, it can be expected, that the radio channel frequency response is different from the one modeled in the ITU channel models for WCDMA. 3GPP has, therefore, decided to extend the existing ITU channel models to cater for the larger delay spread of the wider band radio channels in LTE.

The new *channel models* are called Extended ITU Models and cover the following types:

- Extended Pedestrian A - EPA
- Extended Typical Urban - ETU
- Extended Vehicular A - EVA

In TEMS CellPlanner the channel models are selected in connection with the data rate mapping tables in the terminal editor, see figure below. For details refer to the options for UL and DL data rate mappings in the *TEMS CellPlanner LTE User's Guide*.

The choice of channel model defines the set of data rate mapping tables that are applied for calculation of the achieved UL and DL data rates in TEMS CellPlanner.



Depending on the speed of the terminal a certain *doppler shift* applies to the carrier frequency. The Extended ITU Channel Models reflect the different doppler shifts of 5 Hz (low shift), 70 Hz (medium shift) and 300 Hz (high shift), which correspond to terminal velocities of approximately 2, 30 and 130 km/h respectively.

2.5 Spectral Efficiency Techniques

eNodeB transmitters send reference signals to UEs, which measure the radio conditions and report back the highest possible modulation and coding scheme for the moment. The *spectral efficiency technique* applied in the eNodeB decides how to use the UE feedback, which affects the data rate and potentially the capacity.

The spectral efficiency techniques supported in TEMS CellPlanner are as follows:

- C*losed-loop MIMO* requires frequent feedback from the UEs to select an optimal pre-coding in every moment, quickly adapting the transmitter's pre-coding to the channel conditions. This technique yields high performance in low-speed environments, but is not suitable for connections with fast moving UEs as the heavy signaling makes it sensitive to channel variations.
- *Open-loop MIMO* uses a fixed pre-coding and does not require any fast feedback from the UEs, hence this technique is suitable in high-speed environments.

In real networks this technique is configured as a system parameter, but in TEMS CellPlanner it is modeled as a terminal parameter together with the channel model.

Irrespective of spectral efficiency technique, a MIMO capable eNodeB dynamically applies the most efficient transmission scheme according to the channel conditions. Spatial multiplexing with different data streams on each antenna can be applied under good conditions, while antennas switch over to transmit diversity with the same data stream on both antennas when the channel quality is lower.

The selection of spectral efficiency technique is relevant only when calculating DL data rate for 2x2 MIMO connections.

2.6 Data Rate Mappings

Each supported combination of UE speed (corresponding to doppler shift), channel model, and spectral efficiency technique has its own *data rate mapping table* in UL and DL respectively, with values from a *link curve*. Link curves map the data rate per RB as a function of SINR.

The LTE Analysis retrieves the highest possible bit rate per cell from the link curve corresponding to the selected data rate mapping of the terminal, considering the configured cell capabilities in terms of number of tx antennas and MIMO support.

Each downlink data rate mapping table contains mappings for 2x2 MIMO (one for closed-loop MIMO, one for open-loop MIMO), 2x2 Tx diversity and SIMO. Which mapping that will be used depends on the capability of the cell. If the cell is capable of using both 2x2 Tx diversity and 2x2 MIMO, the best of those schemes will automatically be selected dependant on the SINR. At high SINR, the data rate mapping corresponding to the selected spectral efficiency technique of 2x2 MIMO is applied. At low SIR, TEMS CellPlanner selects 2x2 Tx diversity automatically when this gives higher data rate.

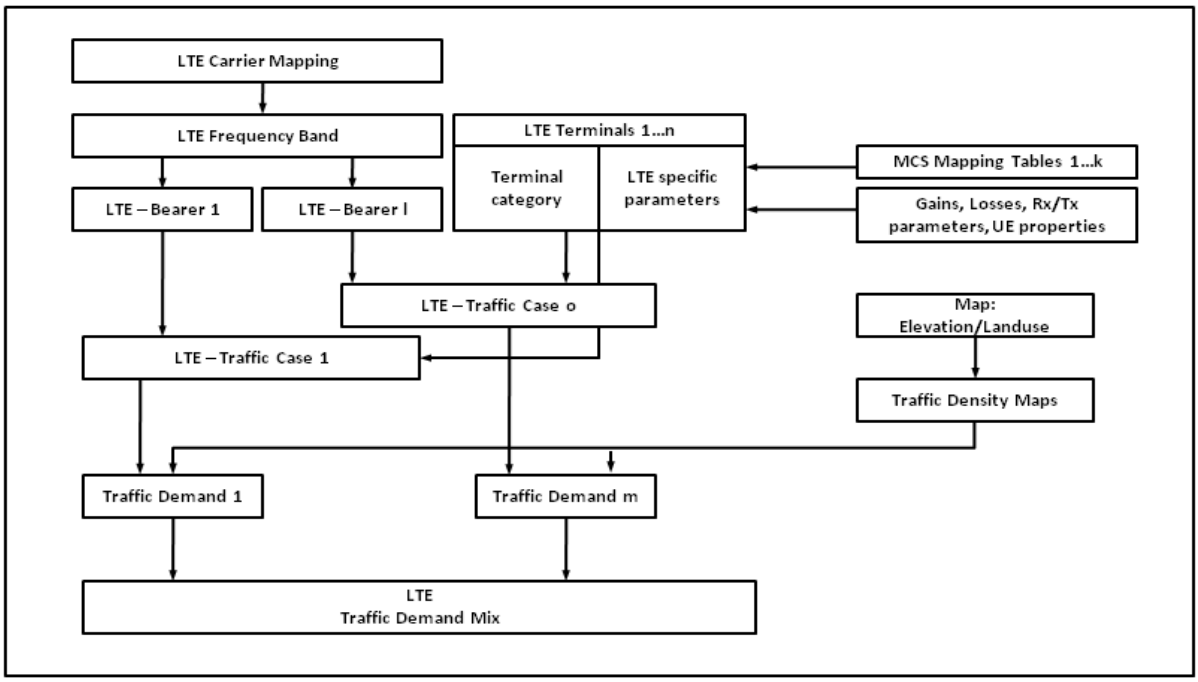
Each uplink data rate mapping table contains a mapping only for SIMO (also called 1x2 MRC), hence there is no 2x2 MIMO or Tx diversity in the uplink. The algorithms and link curves assume that cells use 2 Rx antennas. In case you have configured a cell to use 1 Rx antenna, the calculated SINR is decreased by 3 dB to find the corresponding UL data rate. Also, if you have configured use of 4 Rx antennas, the same mapping as for 2 Rx antennas will be used (limitation in current version).

(SINR = C/(I+N)).

2.7 LTE Frequency Band, Terminals, Bearers and Traffic Cases

For the LTE Analysis as well as for Plot and Report Generation different properties of the LTE system, of base stations and of terminals need to be combined. This chapter provides background information on how these properties relate to each other and in which context they are used in TEMS CellPlanner.

A general overview on how system and equipment properties are mapped to each other is provided in the following figure:



The LTE Analysis takes terminal, base station and system parameters into account and generates plots and reports for -so called- Traffic Cases. A Traffic Case is a combination of an LTE bearer and a terminal. This way, the network planner can evaluate the expected performance of the network for different terminals using LTE bearers with different QoS and priority settings. A Traffic Case is -in other words- a representation of a subscriber class that is using a certain terminal type and a certain LTE bearer.

The Monte Carlo Simulator in the LTE Analysis generates mobile terminals based upon a traffic demand mix. In a traffic demand mix one or several traffic cases are combined with their respective traffic demand (either with uniform or with a map-based or area-based distribution).

An LTE bearer comprises of an LTE frequency band. Some of the properties of the LTE Frequency Band are defined by the LTE Carrier Mapping.

The terminal comprises of a terminal category and LTE specific parameters. Such parameters are data rate mapping tables and radio related parameters, some of which can be edited by the user.

During the LTE analysis all above parameters are applied in an appropriate manner. For details on how the different parameters influence the results of the LTE Analysis refer to chapter Influence of Parameter Settings on Analysis Results on page 3-15.

2.8 Planning of Fixed Subscribers in LTE

TEMS CellPlanner allows advanced analysis of fixed subscribers in an LTE network. The properties of fixed subscribers differ from those of mobile terminals. The following attributes are considered in the LTE Analysis for fixed subscribers:

- Fixed subscriber positions are edited manually or imported using a TEMS CellPlanner import function.
- Fixed subscribers may use a directional antenna, which provides a certain side-lobe attenuation for interfering cells that are not co-located with the best serving cell. The side lobe attenuation of the terminal antenna is set in the terminal editor. For the serving cell of a fixed subscriber the full antenna gain without side lobe attenuation is applied in the algorithms.
- Fixed subscribers may use the same LTE band, LTE terminal types and LTE bearers as the mobile terminals. There is no need to assign separate bands or bearers to fixed terminals. The traffic cases used for mobile terminals may also be applied to fixed subscribers.
- The pathloss and best server calculations for fixed subscribers are part of the LTE Analysis algorithm, including plot and report generation. For details see chapter Simulator Structure for LTE Analysis on page 3-5.
- Simulation of random fading is not applied for fixed terminals as they do not move in the network.
- Slow fade margins (log-normal fading) are applied to fixed subscribers in the same manner as for mobile terminals. The fade margin is position (bin) dependent.
- User scheduling and resource allocation is during the LTE Analysis combined with the resource allocation of mobile terminals depending on the traffic cases selected. Only fixed subscriber positions that allow simultaneous UL and DL connection to the serving cell are allowed to compete with mobile terminals for resources in accordance with their QoS and priority settings.
- The position of fixed subscribers is unchanged during the entire simulation of the LTE network, unlike mobile terminals, the position of which may be generated for each trial in a random fashion.
- The traffic demand for fixed subscribers is derived from the density of subscribers as defined by their location in the LTE network coverage area.
- Fixed subscribers are during the LTE Analysis not part of the traffic demand mix (as defined for mobile terminals) since their traffic demand is handled separately. This is connected to the requirement of fixed positions, which has an influence on how the random user generation algorithm of the Monte Carlo Simulator generates and distributes mobile terminals.

2.9 Current Limitations in LTE System Modeling

LTE Systems are currently being deployed in large network roll-outs. The LTE system performance parameters that are available today for network planning are derived mainly from link and system simulations. Adjustments of these parameters are required as soon as more real network performance data becomes available.

Furthermore, the 3GPP Standards for LTE support a wide range of different functions and features for LTE eNodeB and terminal equipment. Not all of these functions are implemented in currently available equipment.

For these reasons TEMS CellPlanner does currently not support the following functions:

- Use of multiple LTE frequency bands
  TEMS CellPlanner (9.0) enables planning of one LTE frequency band only. This limitation has an influence on the LTE Analysis function and on resource allocation as well as on the Neighbor List planning and the Cell ID planning algorithms.
- Multi-user MIMO
  The current implementation of MIMO modeling does not cater for multi-user detection functions.
- Extended cell range
  The modeling of LTE eNodeB and the pathloss predictions do not consider Extended Cell Range functionality in LTE.
- Interference Rejection Combining and Inter-cell Interference Coordination
  These functions are currently not modeled in TEMS CellPlanner.
- Maximum 2 Rx antennas in cells
  Even if you configure 4 Rx antennas, calculations will ignore this setting and use 2 Rx antennas.

The planning algorithms and capabilities of TEMS CellPlanner will be updated as soon as there is simulated or measured performance data for these functions available.

3
LTE Analysis - Details for Advanced Users

This chapter provides a detailed overview of the LTE Analysis Module in TEMS CellPlanner. In this document it is assumed that the reader has already general knowledge on setting basic analysis parameters and on running the LTE Analysis.

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3.1 On Simulators for LTE Network Planning

The LTE System applies sophisticated algorithms of Radio Resource Management for connecting users and terminals to the network. Besides sharing the same radio resources the traffic management algorithms are designed to provide maximum spectrum efficiency, i.e. the maximum data throughput for a given radio spectrum. This involves intelligent scheduling of users in good radio conditions for high data rates while providing users in worse radio conditions with a minimum average data rate for the requested services to run properly. Some users in the network require a high Quality of Service with guaranteed bit rates for their connection while other users are satisfied with a good average bit rate, independent of their position in the network.

In a mobile network, users move with varying speed between the cells, which leads to an always fluctuating traffic load in the cells.

Furthermore, LTE is a packet switched data system for mobile and fixed applications. The nature of packet data traffic is bursty, with users being active or inactive at different points in time. The user activity/inactivity is hard to predict in a planning tool.

All these conditions call for a radio resource management, which takes a multitude of radio, network and user dependent parameters into account. Such user traffic handling cannot be modeled in a planning tool straight forward. Instead, advanced simulation algorithms are used to model the expected user and network behavior under varying traffic load and radio conditions.

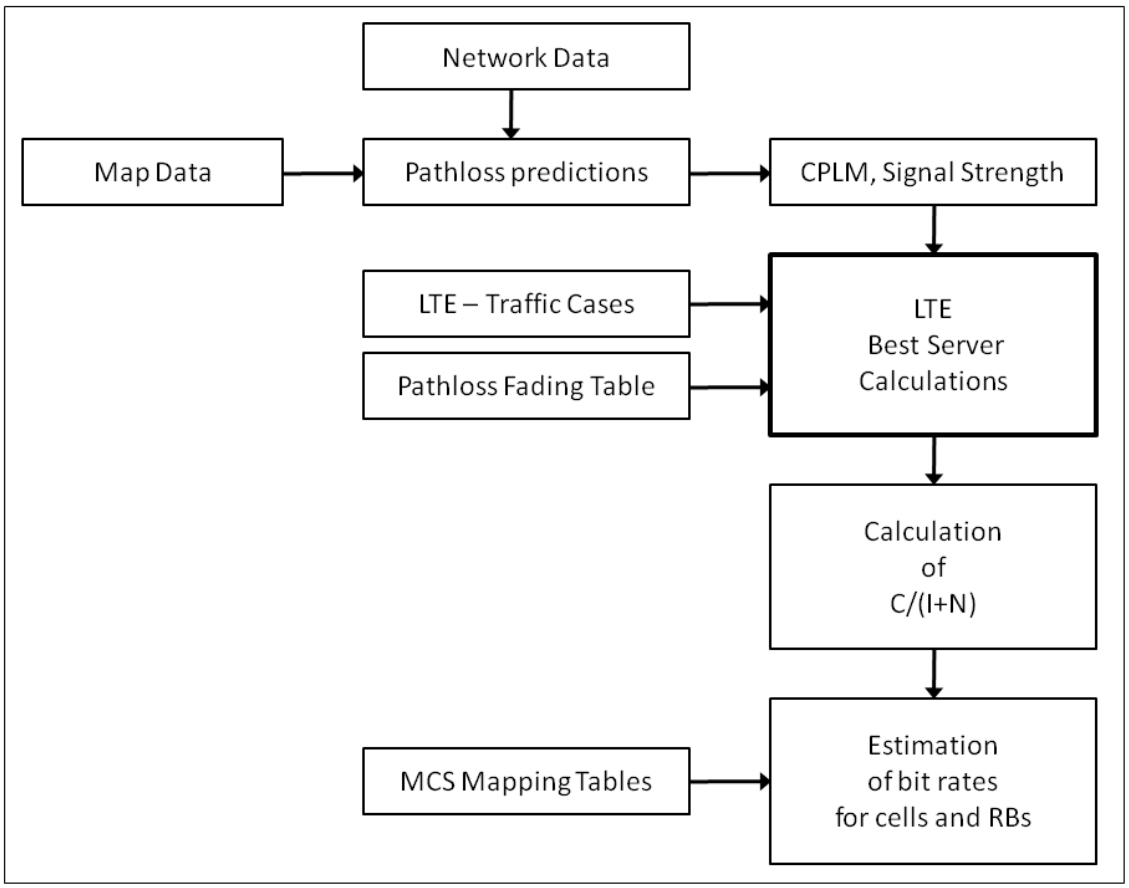
The LTE Analysis algorithm in TEMS CellPlanner is based on a sophisticated Monte Carlo Simulation Engine. A large amount of random number generators models the input conditions of the simulator. The simulator engine aims at maximum spectrum efficiency of the radio network. Based on a user defined number of trials, the simulation algorithms model the mobility and activity behavior of mobile users. Once a trial has converged to a stable state, intermediate data on user connections and on achieved data rates in UL and DL are collected and a new trial with the same or a different user distribution in the network is started. After running a number of trials the calculation results are evaluated in a statistical manner, to assess the performance of the network and to optimize the network plan.

The results of the LTE Analysis are input to other planning functions in TEMS CellPlanner such as the Cell ID planning and optimization. This algorithm is described in chapter LTE Cell ID Planning in this Technical Reference Guide.

3.2 Best Server Analysis for LTE

In a multi-cell radio network such as LTE most of the expected user positions are covered by several cells of LTE base stations. It is, therefore, important to find for every position in the network (in TEMS CellPlanner called a *bin*) the best serving cell and cells that might act as second or third best server or as potential interferer.

TEMS CellPlanner uses the Best Server Analysis algorithm to find such list of best servers for all bins in the network. The following figure shows an overview on the input and output functions of this algorithm.



Before the Best Server Algorithm can be run, the network and map data needs to be provided by the planner and the pathloss prediction results must be available.

Based on the pathloss predictions from all cells to all bins in the network a composite pathloss matrix (CPLM) is generated, which contains for every bin only those cells that fulfill the input requirements set by the planner.

For every traffic case, as defined in the traffic demand mix, the best server algorithm finds those cells that cover a bin for the respective traffic case(-s) with a minimum signal strength. As the LTE network applies a frequency re-use of 1 and there are more than one cell covering most of the bins in the network there is a risk for mutual

interference between the cells. Taking the amount of cells and their corresponding signal strength into account, the best server algorithm calculates the signal quality of the best serving cell as C/(I+N) for every bin.

In order to serve a bin with a minimum data rate a certain signal quality from the best serving cell is required. The data rate is retrieved from the data rate mapping tables as well as from the network properties in terms of DL Transmission Scheme and taking the achieved signal quality into account.

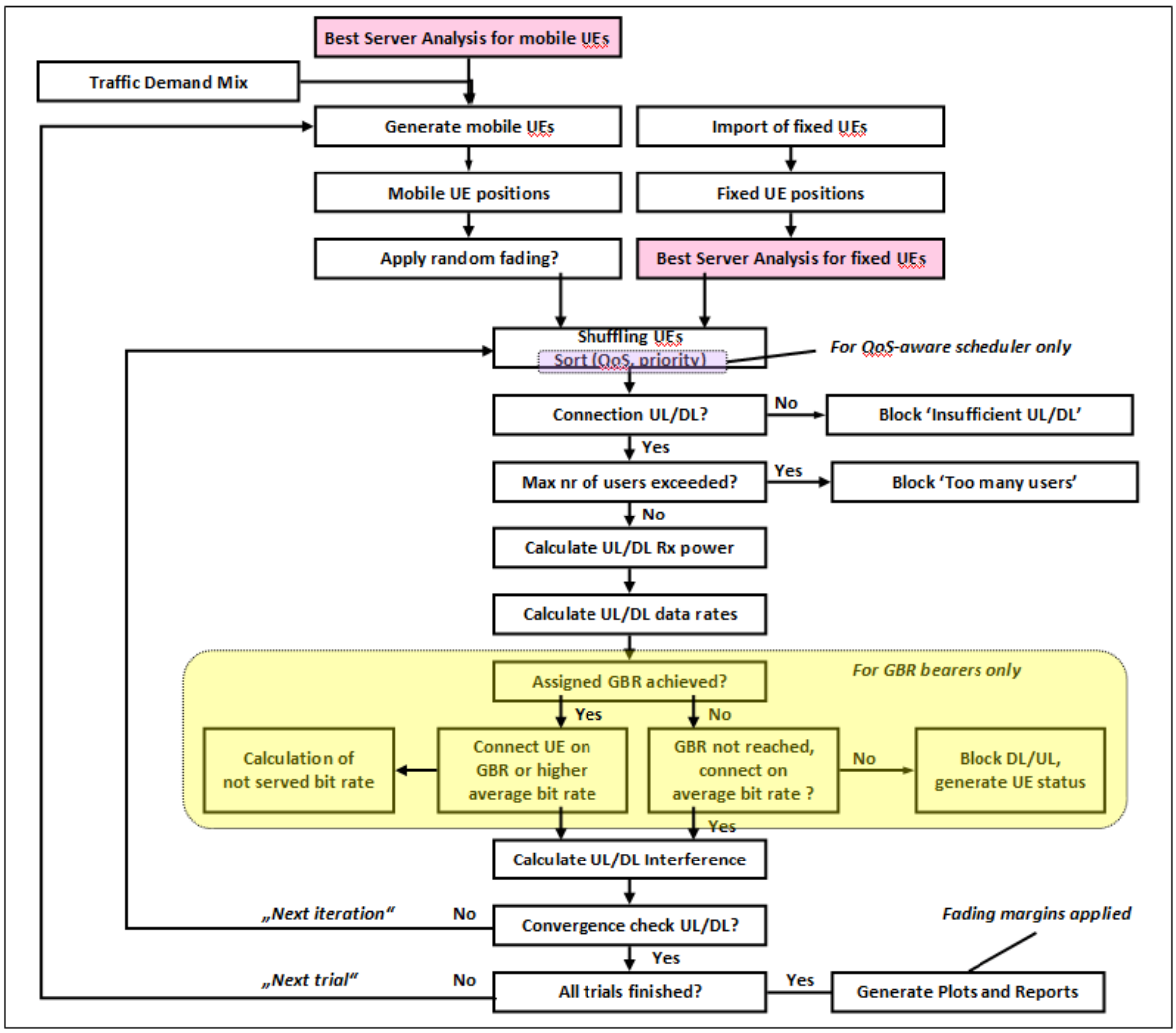
The output of the Best Server Analysis is a list of Best and n-best servers and with the achieved C/(I+N) for every bin in the unloaded network. This information is fed into the LTE Analysis module for simulation of subscribers and traffic.

Note: *Observe that the Best Server Algorithm as described above only operates on mobile subscribers. The Best Server Analysis for fixed subscribers is part of the LTE Analysis Algorithm and is described in chapter* "Simulator Structure for LTE Analysis"*.*

3.3 Simulator Structure for LTE Analysis

This chapter provides an overview on the main simulator principles implemented in the LTE Analysis of TEMS CellPlanner.

The following figure shows how the most important functions of the simulator are designed, a simplified description of which is provided in the paragraphs below.



Based on the input data from the "Best Server Analysis for LTE" and on the traffic demand as specified for each traffic case in the traffic demand mix mobile terminals are generated in the best server coverage areas of the cells. The bin position of these terminals is now locked for the duration of the current simulator trial.

If the option "Use Random Fading" is selected for the LTE Analysis, the calculated signal strength values for UL and DL for the best serving cell and all interfering cells in every bin will be altered with a randomly generated up- or down-fading component. This implies that another cell than the original best serving cell of a

mobile UE may become its best server. For fixed subscribers random fading simulation is not applied.

In case the network plan shall also cater for fixed subscribers, the planner can select fixed subscriber positions based on an imported subscriber list or manually generated fixed subscriber positions. The LTE Analysis module runs a pathloss prediction for all fixed subscriber positions to all cells in the network and performs a best server analysis similar to the algorithm for mobile terminals. For calculation of the signal quality from the best serving cell, the possible use of directional antennas at the fixed subscriber position is considered by taking the antenna side lobe attenuation (terminal parameter) of the fixed subscriber antenna into account.

In the sub-sequent algorithms the fixed and mobile subscribers are treated in a similar manner by the LTE Analysis, i.e. they have to compete on equal basis for the cell capacity resources.

If for an LTE radio bearer a non-zero value was set for the Guaranteed Bit Rate in UL and/or DL, this bearer will be treated as a QoS bearer. All fixed and mobile subscribers using this bearer in the current trial of the simulation are now sorted in accordance with their QoS class (GBR or non-GBR). Within their QoS class the subscribers are sorted in accordance with their LTE bearer priority. The output of this function is a sorted list of subscribers with their respective traffic case, which shall now be scheduled for a connection to the network.

The scheduling starts with an UL/DL connection check for the scheduled users. If the minimum data rate for a scheduled subscriber can be achieved, the algorithm calculates an activity factor for UL and DL for this user. If the user connection check fails, the subscriber is marked disconnected and the corresponding status flag is set. The reasons for blocking subscribers in the LTE Analysis are described in chapter "Reasons for Blocking of Users during Simulation".

Users are first ensured to be connected in UL. The main reason for this limitation is that DL Power Control and Link Adaptation rely on CQI measurements and reporting of the terminals in the UL. Users that are connected and active on UL can now be scheduled also for DL connections.

If a Guaranteed Bit Rate (GBR) has been set for the Radio Bearer of the scheduled subscriber, the algorithms check whether or not this GBR can be achieved. Depending on the capacity resources of the serving cell, the subscriber might be connected with the requested GBR or with a higher average bit rate. All cell capacity that is not used by subscribers in a cell is calculated and reported as “Not served data rate”.

A GBR-subscriber that cannot be connected on GBR is blocked and the subscriber status is recorded. The algorithm continues with the next subscriber in priority order.

Subscribers with a bearer setting “Reject on resource shortage” set to true are blocked in case the cell capacity is not sufficient to connect this subscriber with the requested bit rate. The subscriber status is recorded and summarized after the simulation in the statistics report.

For all connected users the required UL and DL received power is calculated and UL and DL transmit power is assigned. Based on the known transmit power values the UL and DL interference can be calculated for every bin.

Depending on the calculated interference, which is generated by all active subscribers, the power assigned for cells and terminals may be adjusted within the capabilities of the terminals and cells. As long as there is an adjustment of assigned power values required, the received interference will change and a new interference calculation needs to be performed.

The convergence check evaluates changes in UL interference in the cell and in the DL transmit activity status between two consecutive iterations. If the UL interference does not change by more than the convergence limit (LTE Analysis parameter) defined in dB by the planner, the UL is considered stable and convergence is reached. For the DL convergence is reached if the DL activity status ("transmitting in DL" or "DL switched off") did not change, i.e. the DL status is stable.

As long as there are cells that did not reach convergence a new iteration will be started, beginning with UL and DL connection checks for the subscribers. A new iteration can be initiated as long as the maximum number of iterations for each trial as defined by the planner is not reached. If the maximum number of iterations has been reached and the network has not converged to a stable state yet, the trial is set to status "unsuccessful" and a new trial is generated, starting with a new random selection of subscribers and of their position in the network.

If convergence has been reached for the network, the final power settings for cells and terminals are used to calculate the UL and DL interference and the received signal quality as C/(I+N). Applying the data rate mapping tables in accordance with the terminal capabilities, the achieved UL and DL data rates are calculated. For this calculation the log-normal fade margins are not considered, since it cannot be assumed that all active and connected subscribers are subject to down-fading at the same time.

If there is still one trial to be done by the simulator (maximum number of trials not reached), the next trial starts with a random generation of subscribers (UEs) in the network.

If the last trial has been performed, final calculations are done and the plots and reports are generated and stored on the hard-disk.

The final calculations include the following parameters:

- total UL and DL utilization and update of link utilization in the cell editor
- number of served and blocked subscribers
- achieved data rates of served users and data rates not served or blocked. The data rate plots are generated from these values.
- cell activity parameters depending on the link utilization. The cell activity is controlled by a random algorithm and simulates changes in cell activity/ inactivity for UL and DL. This feature reflects the bursty nature of packet data transmission.

- calculation of statistical values from all trials (minimum, maximum, average parameter values and their standard deviation). The average value of the calculated parameters is used for plot generation.
- inclusion of fade margins in plot values of signal strength and UL power margin

A description of plots and reports generated by the LTE Analysis is provided in the *TEMS CellPlanner LTE User's Guide*.

3.4 Scheduler Options

The scheduler in the LTE eNodeB is an advanced algorithm for radio resource management, which assigns radio resources to subscribers while taking the following main conditions into account:

- UL and DL cell activity
- UL interference and noise rise
- achieved signal quality of individual subscriber connections (reported by terminal through CQI-messages)
- QoS requirements and priority of radio bearers
- data rate requirements in UL and DL for individual subscriber connections
- number of available Resource Blocks
- number of available LTE carriers
- number of maximum allowed UL and DL users
- options for Time Spread Allocation (TSA), i.e. the scheduler allows simultaneous sharing of capacity resources between different users on the UL.
- options for bit rate shaping for active subscribers, i.e. the scheduler sets an upper limit on the bit rate that can be allocated to a subscriber
- resource blocks are randomly allocated per carrier according to the principle of so called random frequency allocation

The Monte Carlo Simulator in TEMS CellPlanner is designed to model these functions in order to provide a realistic evaluation of the expected LTE network performance.

This chapter describes the different scheduler options that are integrated into the simulation engine for the LTE Analysis for both UL and DL modeling.

3.4.1 Round Robin Scheduler

The Round Robin scheduling algorithm assumes that the active subscribers have equal weight and priority and assigns the UL and DL resources in such a way that as many users as possible are connected with nearly equal data rates. In this concept the subscribers are connected in random order with their average bit rate. There is no sorting of subscribers and consequently, any settings for QoS or priority requirements are ignored by the scheduler.

The scheduler assigns capacity resources until the maximum DL load is reached. Another limiting parameter is the maximum number of subscribers per cell.

Once the capacity resource limit is reached, admission control algorithms will block new connection attempts of subscribers. Those subscribers that use LTE radio bearers with checked option “Reject on resource shortage” are blocked first. All remaining subscribers are blocked in random order.

In case there is a high number of connection attempts to the cells, the scheduler will divide the available capacity into approximately equal shares.

In cases of only few connection attempts and when there is unused capacity available in the cell, the scheduler randomly assigns a higher share of capacity resources to some users. One of the reasons for certain "remaining" capacity is the fact that subscribers in favorable radio conditions might not require a full (equal) share of the assigned capacity resources to achieve the requested average data rate. In such a case the "spare capacity" is distributed to users in less favorable conditions to increase their share of the resources and thereby also their achieved data rates.

The Round Robin scheduler has the main focus on fairness in distribution of capacity resources to as many subscribers as possible.

3.4.2 Channel Dependent Scheduler

The channel dependent scheduler optimizes the capacity assignments in such a way that subscribers in favorable radio conditions get a larger share of the available capacity resources. Subscribers in less favorable radio conditions are served on a much lower data rate with the aim to satisfy their minimum data rate requirements.

The main mechanism in the channel dependent scheduler is an evaluation of the achieved signal quality and an assignment of weighting coefficients for active users. Subscribers with a high achieved C/(I+N) are assigned a higher weight than subscribers in less favorable conditions. As a result, the scheduler assigns a larger amount of capacity shares to subscribers in good radio conditions. Once these users are served on their maximum achievable data rate, the remaining capacity is shared between subscribers with lower weighting coefficients. The scheduler also applies sharing of the UL channel resources (Time Spread Allocation - TSA and bit rate shaping) during the simulation.

The channel dependent scheduler prioritizes maximum spectrum efficiency (highest cell throughput for a given capacity pool) at the expense of fairness in resource sharing.

The remaining functions of the scheduler are similar to the Round Robin scheduler. There is no sorting of subscribers based on QoS or priority requirements in the LTE radio bearers. Subscribers on radio bearers with the option "Reject on resource shortage" set to true are blocked first in a random fashion in case the cell load limits are reached.

The channel dependent scheduler can achieve a higher data rate for some of the users and can increase the total cell throughput as compared to the Round Robin scheduler. This results in a certain scheduling gain, which can be entered by the network planner as a parameter for the scheduler options in the LTE Analysis window.

3.4.3 QoS Aware Scheduler

This scheduler takes QoS settings and priority for radio bearers into account. If the planner has set a non-zero value for the Guaranteed Bit Rate on UL and/or DL for a radio bearer, this bearer is considered a QoS bearer granted a certain bit rate. This has a strong influence on the sorting of subscribers in the scheduler for connection attempts. Also, the priority of the bearers is considered when sorting subscribers within the same QoS class (GBR or non-GBR).

The first operation of the scheduler is the sorting of subscribers in accordance with their QoS and priority settings. In case the maximum number of users is exceeded, the simulator's signaling resources are not sufficient. Those at the end of the sorted list will be blocked first with blocking reason "Too many users" in order to allow higher priority subscribers to get connected.

The next operation of the scheduler involves evaluating if the requested bit rate can be satisfied for the scheduled subscribers. This algorithm takes the user-defined scheduling gain into account. If the requested bit rate is higher than the available one, these subscribers are blocked with the reason "UL (or DL) overloaded".

In case the load limits are still exceeded at subscriber connection attempts, non-GBR subscribers are blocked starting from the end of the sorted priority list. Those subscribers on radio bearers with the option "Reject on resource shortage" set to true are blocked first.

If these measures did not resolve the overload situation the scheduler identifies GBR-subscribers and blocks them one by one, starting with the subscribers with lowest priority, until the overload is resolved. The blocking reason is set to "DL (or UL) GBR not reached".

In the case that all subscribers on GBR radio bearers have been served by the network in accordance with their requested bit rates, the remaining cell capacity is shared by active subscribers on equal priority in accordance with the Round Robin scheduling principles until the maximum assigned UL and DL load is achieved.

The QoS aware scheduler favors high priority subscribers with a guaranteed bit rate assignment to the largest possible extent. Lower priority subscribers without bit rate guaranteed share the remaining resources in a fair manner (Round Robin).

3.5 Reasons for Blocking of Users during Simulation

The capacity resource assignment in the Monte Carlo Simulator is based on the parameter settings for UL and DL capacity in the cells, on requested capacity resources by subscriber connection attempts, on QoS and priority settings for LTE radio bearers, on the achieved signal quality for the subscriber positions in relation to their serving cell and also on the selected scheduling algorithm.

A large number of random processes in the simulation engine models the bursty nature of packet radio transmission, the varying activity of cells and subscribers on UL and DL as well as the changes in transmitter power assignments of cells and terminals and the fluctuations in the interference situation in the network. As a result of these random algorithms the subscribers may or may not be connected to the network during a trial. The connection status of each subscriber is recorded for each iteration of a random trial. Once the system converges towards a stable state at the end of a trial the final subscriber connection status is stored for statistical processing. For subscribers with the connection status "Blocked" the blocking reason is provided in the statistical reports.

The blocking statistics are part of the LTE Reports. The report summarizes the amount of subscriber connection attempts that were blocked during the simulation for different reasons.The following paragraphs describe the subscriber connection status and possible blocking reasons in more detail.

Connected

This connection status is assigned to subscribers, which are connected to the network. In case of subscribers on GBR radio bearers the guaranteed bit rate was achieved. For non-GBR users the achieved data rate is equal or higher than the minimum data rate.

Too Many Users

The maximum allowed number of users per cell is defined by the network planner in the LTE Analysis editor. In case there are more subscribers attempting to connect to the cell than allowed a random blocking of the users (observing bearer priority) takes place. Every subscriber which is blocked during this procedure is assigned the status blocked due to "Too many users".

Insufficient DL

Users that are blocked with reason "Insufficient DL" required a bit rate, which - when assigned to this subscriber in connected mode - would have led to a higher DL utilization than the maximum allowed utilization for the cell. In order to protect the best serving cell of this subscriber from overload in the DL the user was blocked.

Insufficient UL

Users that are blocked with reason "Insufficient UL" required a bit rate, which - when assigned to this subscriber in connected mode - would have led to a higher UL utilization or a higher UL activity factor than the maximum allowed values. In order to protect the best serving cell of this subscriber from overload in the UL the user was blocked.

Rejected in DL

Subscribers on non-GBR radio bearers with the option "Reject on resource shortage" set to true are blocked first in order to resolve an overload situation in the DL. When such subscriber is blocked the status is set to "Rejected in DL" and the subscriber is excluded from further connection attempts.

Rejected in UL

Subscribers on non-GBR radio bearers with the option "Reject on resource shortage" set to true are blocked first in order to resolve an overload situation in the UL. When such subscriber is blocked the status is set to "Rejected in UL" and the subscriber is excluded from further connection attempts.

DL GBR Not Reached

A subscriber on a QoS radio bearer with a non-zero guaranteed bit rate attempted connecting to the DL of the best serving cell. However, the connection could not be established on the guaranteed bit rate, since the load in the cell was already too high for serving this user on the GBR.

UL GBR Not Reached

A subscriber on a QoS radio bearer with a non-zero guaranteed bit rate attempted connecting to the UL of the best serving cell. However, the connection could not be established on the guaranteed bit rate, since the load in the cell was already too high for serving this user on the GBR.

DL Overloaded

Due to high load in the DL a subscriber on a non-GBR bearer did not achieve the minimum requested bit rate of 1 kbps. The subscriber is blocked from DL access and the blocking reason is set to "DL overloaded".

UL Overloaded

Due to high load in the UL a subscriber on a non-GBR bearer did not achieve the minimum requested bit rate of 1 kbps. The subscriber is blocked from UL access and the blocking reason is set to "UL overloaded".

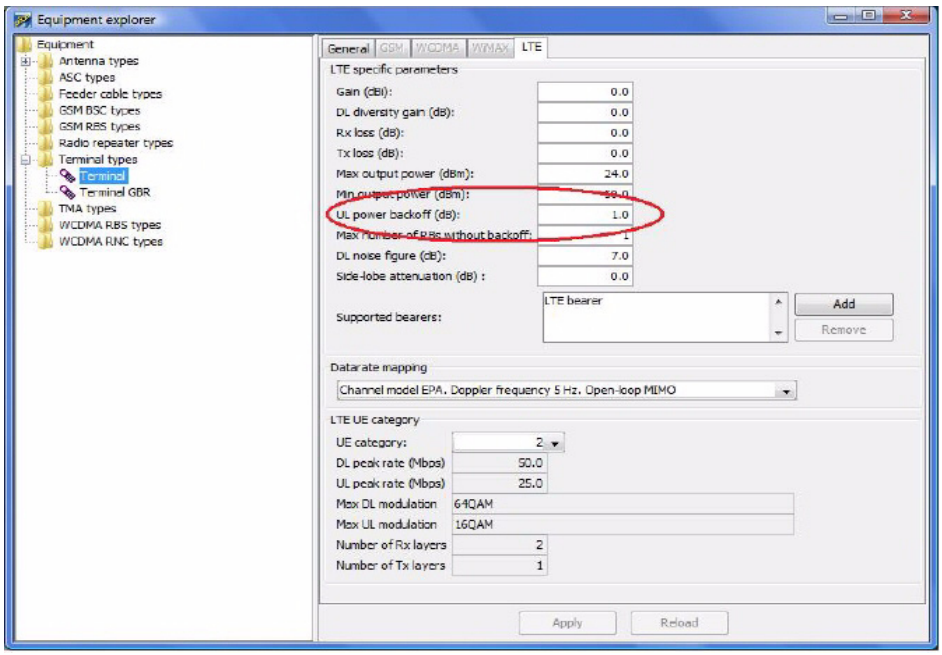
3.6 Influence of Parameter Settings on Analysis Results

The simulation of an LTE radio network in TEMS CellPlanner involves a number of random processes, which are controlled by the simulation engine. Besides the general settings for the simulator there are some radio specific parameters that influence the outcome of the LTE Analysis in a certain manner. For clarification these parameters are highlighted in this chapter.

3.6.1 UL Power Backoff

The UL Power Backoff is a LTE terminal parameter.

Terminals with a high requested UL bit rate would transmit data on more than one RB. Due to the design of the terminal radio transmitter this could lead to non-linear effects in the transmitter chain and to distortions in the transmission. Therefore, a certain power back-off from the maximum terminal output power is required to compensate for possible signal distortions. When the assigned number of RBs exceeds the parameter "Maximum Number of RBs without backoff" the transmit power is reduced by the corresponding backoff value.



UL power backoff is taken into consideration for calculation of the terminal UL power and for calculation of the achievable UL signal quality and bit rate.

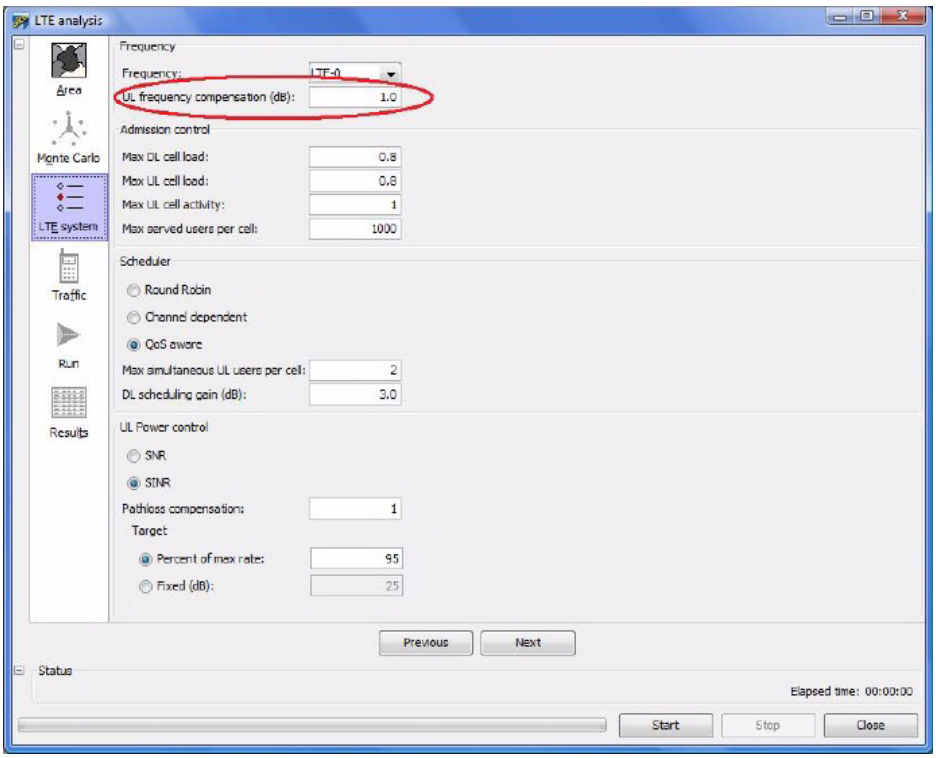
Consequently, setting high values for UL power backoff reduces the received power in the cell and the UL data rate for these terminals.

3.6.2 UL Frequency Compensation

The UL Frequency Compensation is a parameter specific for the LTE Analysis settings. Suitable parameter settings can be found in 3GPP recommendations.

The pathloss predictions in TEMS CellPlanner are based on the selected DL frequency band. Also, the calculation of the best serving cell for each bin in the network is based on the DL Pathloss.

However, for calculation of the achieved UL signal strength the UL pathloss is required. As the frequency sub-band for the UL uses a lower center frequency than the sub-band for the DL, there is a difference between the predicted DL pathloss and the actual UL pathloss. This difference can be considered in the LTE Analysis by setting a compensation factor.



The pathloss value for the UL will then be retrieved from the predicted DL pathloss minus the pathloss compensation factor.

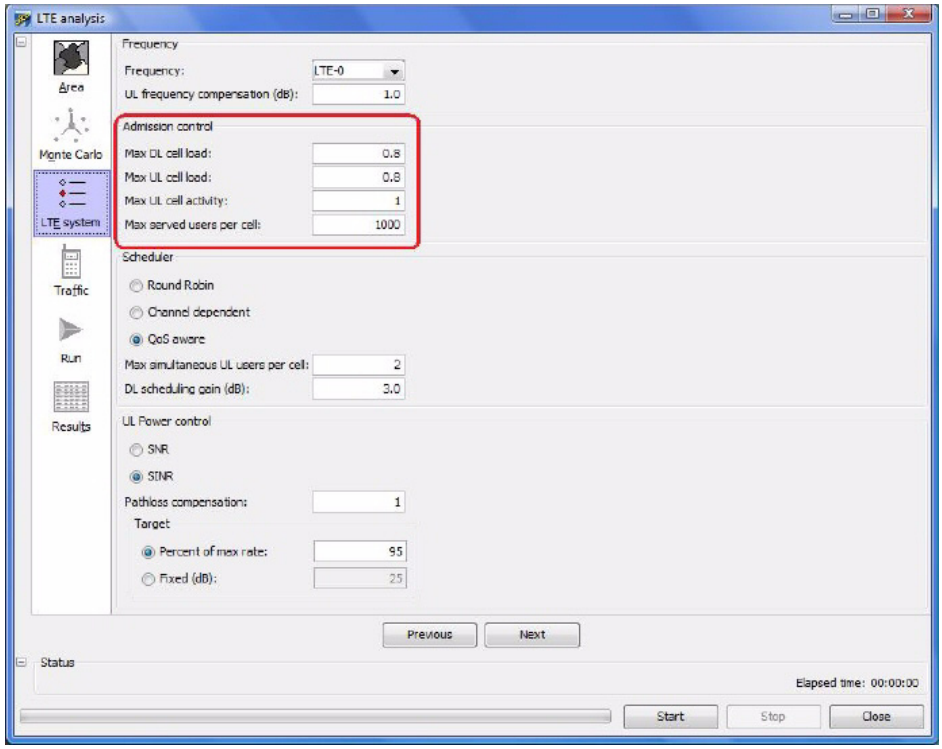
This UL frequency compensation has an influence on the achieved UL signal quality and also on the achieved UL bit rates in the network.

3.6.3 Admission Control Parameters

Admission Control in the LTE Analysis is used to resolve overload situations in the simulated network. The algorithms in the simulator work with the basic capacity resources of the LTE air interface:

- In the time /frequency domain - maximum number of available Resource Blocks (RBs) for UL and DL
- in the time domain - maximum cell activity factor in UL
- maximum number of users per cell

Observe that the admission control parameters are applied on network level and not - as was done in WCDMA - on individual cell level. The admission control parameters are set in the LTE Analysis window, see figure below.



The maximum UL and DL cell load is entered as a percentage fraction value of the total available amount of RBs (basic resource unit in the time/frequency matrix of the air interface) for traffic. The total amount of RBs available for traffic is calculated from the number of resource blocks in the LTE carrier mapping and from the amount of resources that are required for control signaling.

The maximum UL cell activity defines the percentage of time the cell can receive traffic data on the UL. During the LTE Analysis the UL activity is monitored for each cell. When the traffic demands in a cell leads to UL resource limitations the admission control algorithm will start blocking users.

The parameter “Max. served users per cell” limits the amount of users that can be kept in the scheduler for access to the cells.

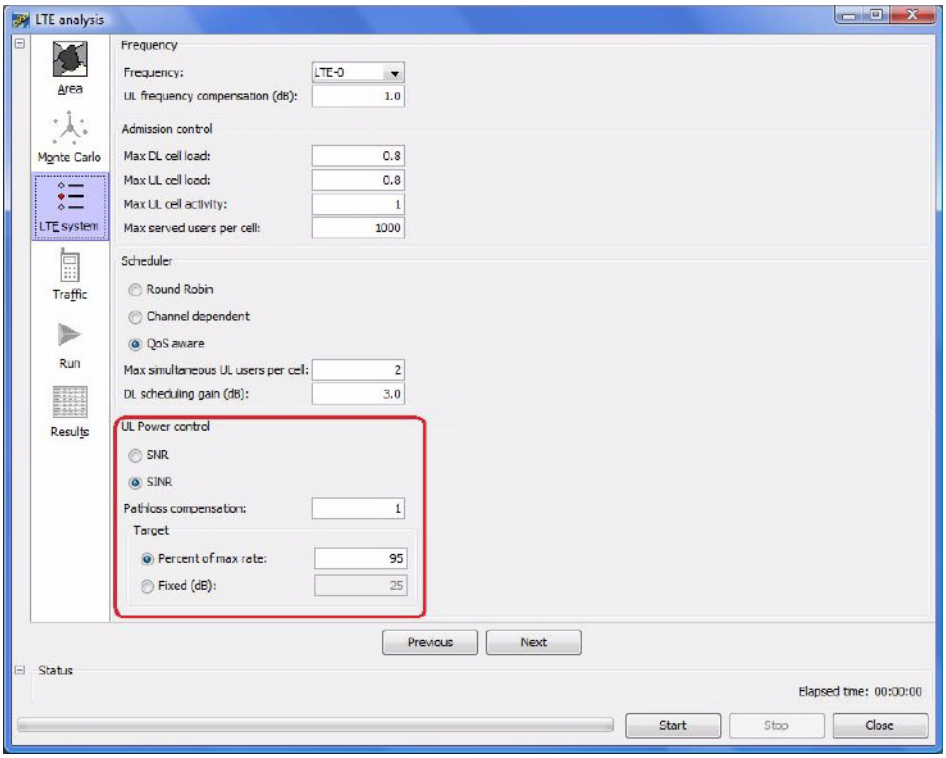
In case any of the admission control parameters are exceeded in any of the cells, the scheduler will start to block user connections depending on the scheduling strategy that was selected by the planner, see chapter 3.4Scheduler Options.

3.6.4 UL Power Control Parameters

The UL power control parameters are set in the LTE Analysis window, see figure below.

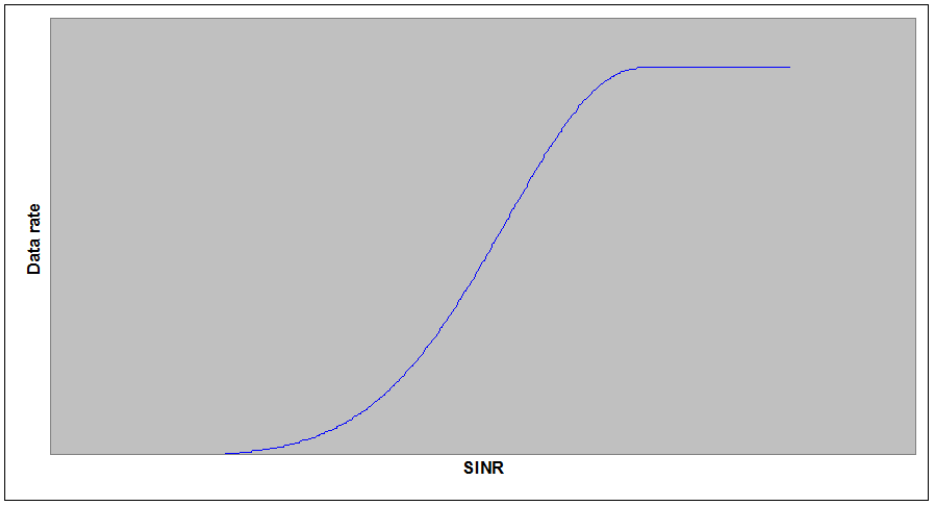
When simulating UL connections for terminals to cells, the UL power is adjusted between different iterations to enable the highest possible achieved data rate for all connected users, yet keeping the interference in the UL of the cells under control. The adjustments of UL power emulate an open-loop UL power control.

When the SNR option is selected the UL power control setting considers UL receiver noise only. The perceived UL interference is not considered for UL power control. This setting usually requires less iterations for a trial to converge.



The option SINR takes both the UL receiver noise and the calculated interference into account. As the interference in the UL might change between iterations, UL power control might require more iterations to achieve a stable connection. This option is more accurate but might require a longer simulation time.

The example below illustrates a typical SINR-to- data rate mapping. As can be seen from the graph, selecting a maximal SINR in power control will yield a very small increase in data rate but require much higher transmitting power. Hence the overall interference in the network will increase and consequently the overall network performance will degrade. This unwanted effect motivates a power control target of 95% (default) instead of 100%.



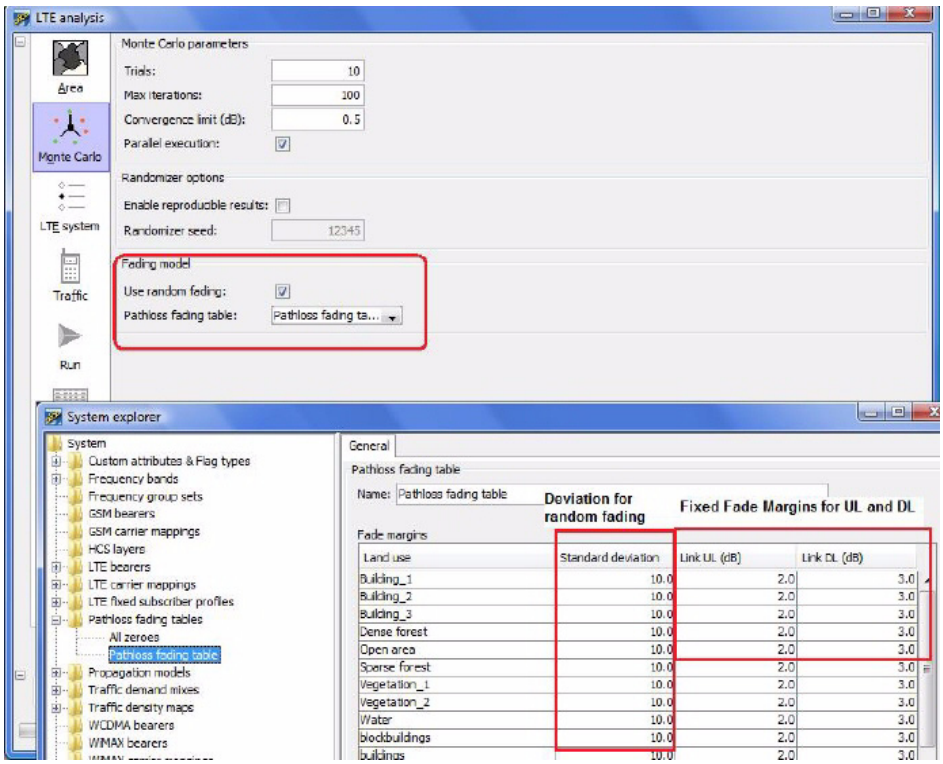
A pathloss compensation factor less than 1 will make the Tx power of terminals far from the serving cell become lower than what is required to get the target SINR. This reduces the interference experienced by adjacent cells, but also reduces the achieved data rate for these terminals.

The power control target can be set to achieve a certain percentage of the maximum achievable UL bit rate for the individual connections. The algorithms in the simulator will then attempt to optimize the power setting towards the specified percentage of the maximum achievable bit rate for every UL connection.

When the power control target has been set to a fixed value the simulator will attempt to set the UL power so that the specified SINR or SNR is achieved.

3.6.5 Simulating Random Fading, Generating Plots with Fade Margins

TEMS CellPlanner provides the option to define pathloss fading tables with land use-based (clutter dependent), see figure below. The pathloss fading tables include fixed fade margin values for UL and DL, as well as standard deviation values for random fading according to a log-normal distribution.



Random Fading

Fixed fading is normally excluded from the TEMS CellPlanner LTE Analysis. However, when the option "Use random fading" is selected, the algorithm for calculation of received UL and DL power will apply a random fading value for each individual UL and DL link between cells and mobile terminals.

Observe that simulation of random fading is not applied to fixed subscribers.

Fade Margins

Fade margins are used to decrease cell sizes, hence giving a better confidence of the coverage close to cell borders. The fade margins to be applied depend on the local radio propagation conditions and are retrieved from detailed drive testing.

Applying fade margins assumes that there is a simultaneous down-fading for all terminals in the cell. Such approach is far too pessimistic for calculation of network capacity and of achieved bit rates. Consequently the fade margins are excluded

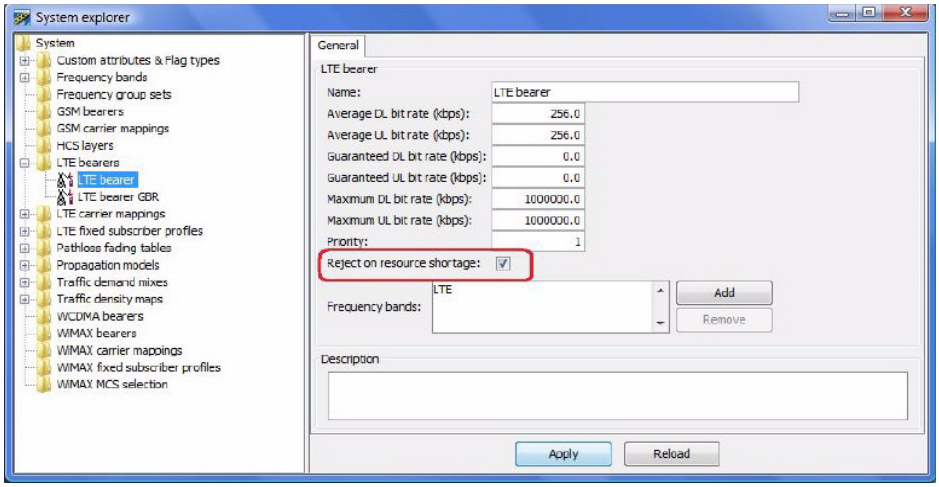
from the TEMS CellPlanner LTE Analysis of the achieved UL and DL bit rates for terminals and cells. Fade margins are however taken into consideration in the plot generation as follows:

- Calculation of the received UL and DL signal strength in the best serving cell and the interfering cells,
- Calculation of the UL power margin.

3.6.6 Rejecting Users on Resource Shortage

This option is selectable in the LTE bearer editor. It controls how overload situations are resolved in the LTE Analysis depending on the presence of guaranteed and non-guaranteed bit rate bearers.

Radio bearers with this option selected are considered by the LTE Analysis as lower priority bearers and are blocked first if the UL or DL capacity is overloaded in a cell, see figure below.

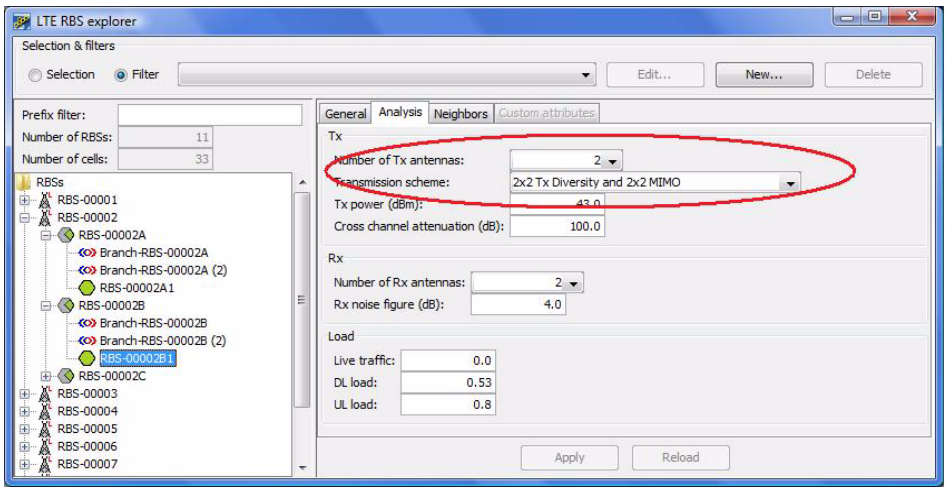


Observe that this option is only valid for radio bearers with a guaranteed bit rate **set to zero** (non-GBR bearers). If a subscriber on such a bearer is blocked it will be reported as "Rejected in UL" or "Rejected in DL" in the LTE Analysis Report.

If there is a resource shortage in UL and/or DL for subscribers on GBR radio bearers (guaranteed bit rate larger than zero) and they cannot be served at this bit rate, their blocking reason is set to "GBR not reached" for UL and/or DL.

3.6.7 Number of Transmit Antennas in a Cell

The number of transmit antennas can be set in the cell editor of an LTE base station. In case a cell has two transmit antennas for transmit diversity or MIMO, the second transmission path creates a certain amount of DL interference in the network. When calculating the DL interference in the serving cell, this interference component is taken into consideration.

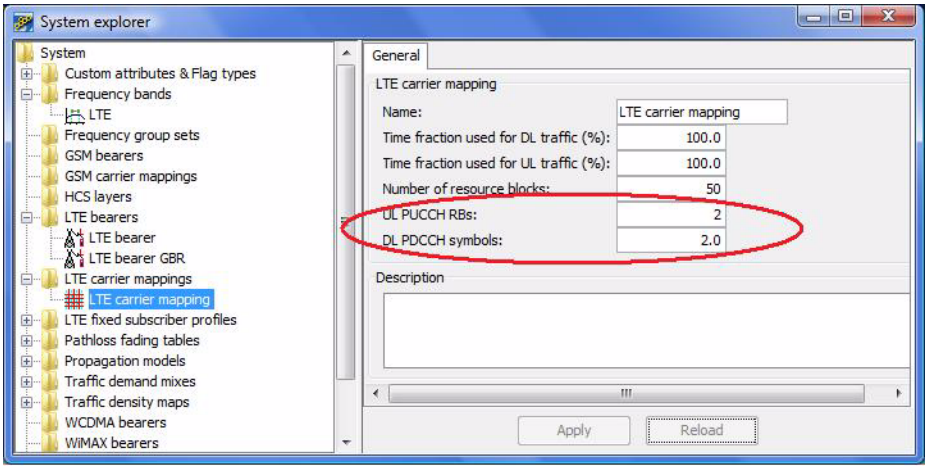


Observe that the number of transmit antennas and the selected transmission scheme also influence the choice of data rate mapping table for calculation of the achieved UL and DL data rates. The reason is the following: In case of transmit diversity there is a gain in achieved signal quality on the DL, which leads to higher achieved DL data rates. In case of MIMO transmission, separate transmission paths are available to the terminal in UL and DL. For instance, in the case of 2x2 MIMO there are two transmission paths and the theoretical DL capacity doubles.

However, for each additional antenna port a certain bandwidth is required for transmission of DL reference symbols, PDCCH information, SCH and BCH data.

For each transmit antenna the cell will send separate reference symbols on the DL. In case of TX Diversity and MIMO DL transmission the terminal has to be able to distinguish between the reference symbols of the different antenna ports.

Therefore, there is a pre-defined position for the reference symbols depending on how many antennas are connected to a cell. The amount of RBs that is used for reference symbols is retrieved from the selected transmission scheme in the LTE cell and the amount of DL PDCCH symbols is defined by the settings in the LTE carrier mapping properties, see figure below.



The more symbols that are required in each transmit path for DL control and for reference symbols the less Resource Blocks are available for data transmission. The number of antennas and the selected transmit scheme of the cell are taken into consideration when calculating the achievable UL and DL data rates.

3.7 Bin Probing in Plot Generation

Plotted data rates could in theory be retrieved as a function of the average SINR over all Monte Carlo trials. Such a simplification would though give unrealistic data rates, as the mapping between SINR and data rate is unlinear and the interference might vary significantly between trials.

To obtain more confidence in the data rate plots, the simulation allows the interference to affect the data rate in each trial. This technique is called *bin probing* with principles as follows:

1. The interference from each Monte Carlo trial is stored for later use.
2. For every bin to plot and every trial, a data rate corresponding to the interference is calculated.
3. The data rate value for the plot is averaged from the calculated data rate values of all trials in previous step.

Bin probing is used when generating the following plots:

- UL power margin
- UL data rate per RB
- UL data rate
- DL data rate per RB (with interference)
- DL data rate (with interference)

Bin probing is thus not used when generating the (non) served data rate plots.

4
LTE Cell-ID Planning

This chapter provides a detailed overview of the LTE Cell-ID planning in TEMS CellPlanner. In this document it is assumed that the reader has already general knowledge on the LTE Radio Interface Specifications.

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4.1 On Cell ID Planning for LTE

The air interface of the LTE radio network is designed such that a frequency re-use of 1:1 can be applied, i.e. all cells (on the selected frequency band) use the same frequency. As the cells cannot be distinguished from each other by their transmit frequency as e.g. in GSM, a different solution for cell identification needs to be implemented.

Already with the introduction of WCMDA, where the cells transmit within a 5MHz carrier on the same frequency, the identification of cells was done using scrambling codes that were unique for each cell in a certain area and a scrambling code planning was required.

The LTE air interface is designed for a high flexibility in the spectrum bandwidth assigned for a cell. The resource allocation is based on resource blocks (RBs), which are parts of a time/frequency matrix. On such a matrix scrambling codes cannot be applied in the same manner as for a WCDMA system.

Instead, the time/frequency matrix of the LTE air interfaces carries cell-specific reference signals on the DL. These signals are used for channel estimation and for coherent detection of the DL transmission by the terminal receivers. The LTE cell ID is based on 3 orthogonal sequences and 168 pseudo-random sequences. Each of the pseudo-random sequences describes a Cell-ID Group. Within each group there are three Cell-IDs, which are defined by the orthogonal sequences. Consequently, the available amount of LTE Cell-IDs is 504 on one LTE carrier.

4.1.1 Cell Search in LTE

The Cell-ID defines the individual reference signal frequency shift between the cells.

Each LTE cell transmits synchronization signals on the Primary (P-SCH) and on the Secondary Synchronization Channels (S-SCH). When a mobile enters an LTE-network the identity of the surrounding cells is not known to the terminal.

Reception of the synchronization channels allows the terminals to find the LTE Cell-IDs of the "visible" cells. The Cell-ID (one out of 3) is encoded on the P-SCH, while the Cell-ID group (one out of 168) is carried by the S-SCH. After detection of both synchronization channels the exact Cell-ID of the best serving LTE cell is known to the terminal.

4.2 Cell-ID Planning in TEMS CellPlanner

Although there are attempts to provide automatic Cell-ID planning by the LTE network itself using "Self-optimizing Network" features, user-controlled Cell-ID planning and optimization is still required for new LTE networks and their later expansion.

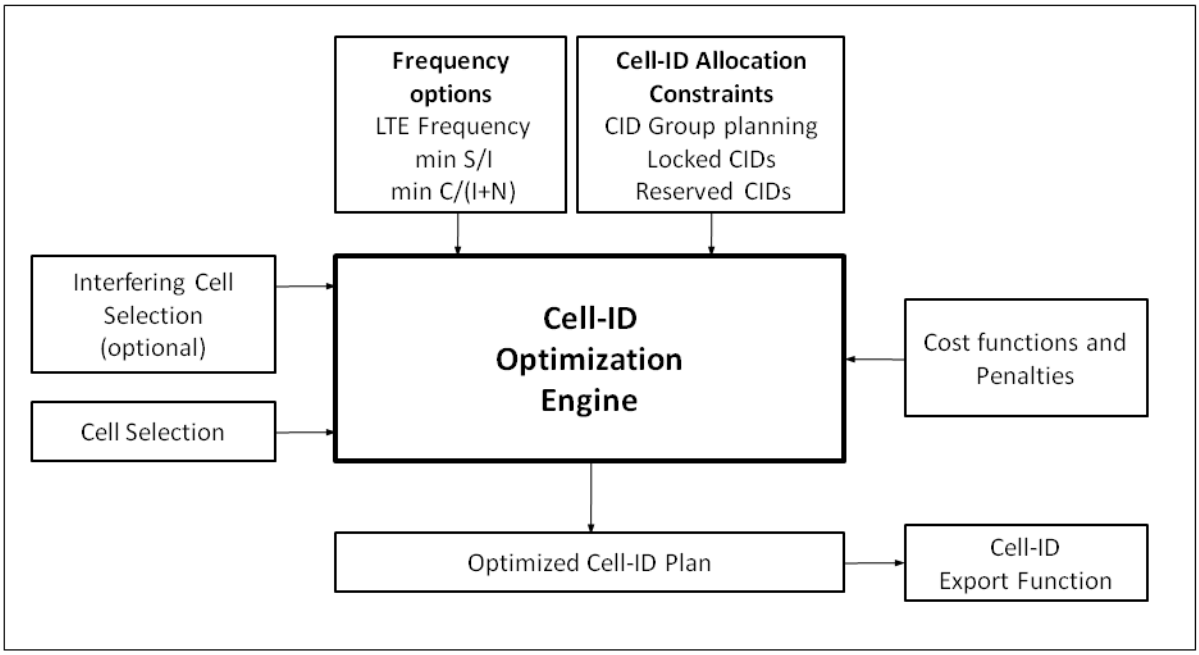
The Cell-ID Planning and Optimization in TEMS CellPlanner is based on best server analysis data. A dedicated planning and optimization algorithm provides means for flexible assignment of Cell-IDs depending on the requirements for the LTE-Network.

The following paragraphs describe the functions for planning and optimization of a Cell-ID plan.

4.2.1 Cell-ID Planning Algorithm

The Cell-ID optimization engine allocates Cell-IDs based on the input data for frequency allocations, Cell-ID allocation constraints, selection of interfering cells (can be imported as an option) and considering cost penalties as defined by the network planner.

The figure below shows the main input data to the Cell-ID Planning.



The Cell-ID planning algorithm provides a high flexibility for locking of Cell-IDs that have already been assigned to some of the cells. If desired, the planner can decide to let the algorithm unlock these Cell-IDs during optimization of the Cell-ID plan against a certain unlock penalty.

For network expansion and for coordination of network roll-out with other operators it might be advantageous to reserve Cell-IDs or Cell-ID groups for later use. TEMS CellPlanner allows to reserve Cell-IDs as a number or a percentage of the total available amount of IDs or ID-groups. Furthermore, the planner can decide to reserve specific IDs or ID-groups. This feature enables coordination of network roll-out on the same LTE-frequency as is used by operators in neighboring countries.

The network planner can also use the same or different ID-groups for the cells of a radio site. The same ID-group can be selected for a site with up to 3 cells, as there are only 3 IDs within a group. When the number of cells at a site exceeds the limit of three cells one or more additional ID-groups might be required.

Important: We recommend using the same Cell-ID group for cells at a site for the following reason. The DL Reference Symbols are transmitted at specified positions in time and frequency, making it possible for the terminal to keep track of the received cell. The Reference Symbol positions are dependent on the Cell-ID. There are six different positions, given by the Cell-ID within the group and by the Cell-ID Group being even or odd. Thus, to ensure that the Reference Symbols transmitted from the three cells at the same site do not interfere with each other, the planner should select to use the same Cell-ID group for all three cells at a site. This results in three different Cell-IDs being assigned to the cells.

When planning and optimizing the Cell-ID allocation the planner can decide to use the neighbor list of the network. This way, conflicting Cell-ID allocations between neighboring cells can be avoided.

4.2.2 Cost Functions for Cell-ID Optimization

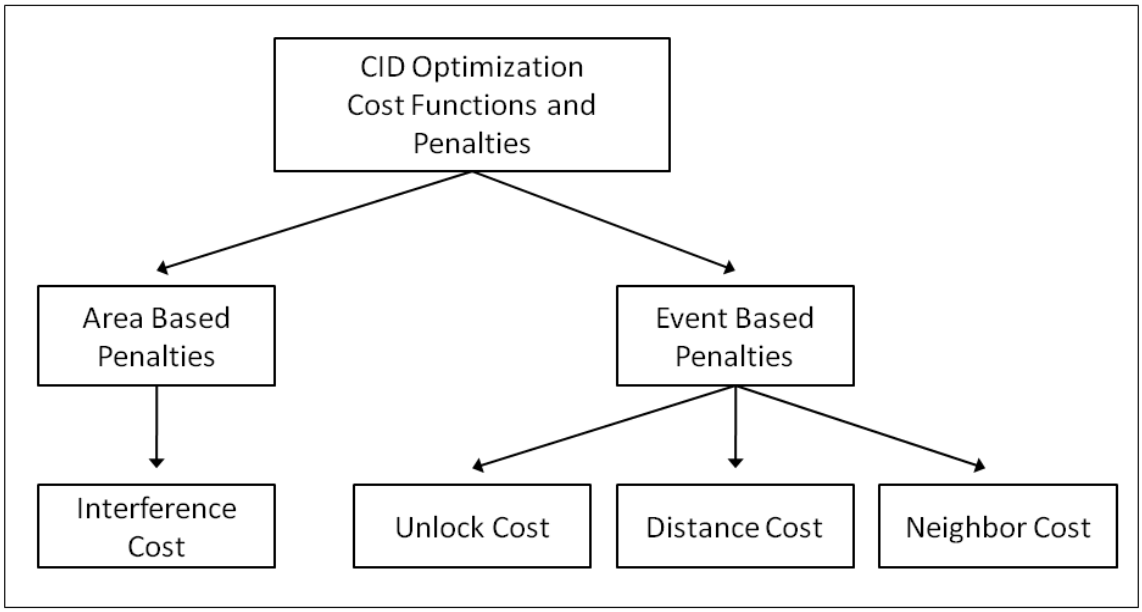
The optimization engine applies different cost functions for evaluation of possible Cell-ID allocation schemes. In an iterative process the optimization algorithm attempts finding the Cell-ID plan with the lowest overall cost given the constraints of the input parameters.

An overview on the costs applied during Cell-ID optimization is provided in the figure below.

The penalties are divided into area based penalties and event based penalties.

4.2.3 Interference Cost

The interference cost is an area-based penalty as it is depending on the number of bins, which are interfered by another cell with the same Cell-ID.



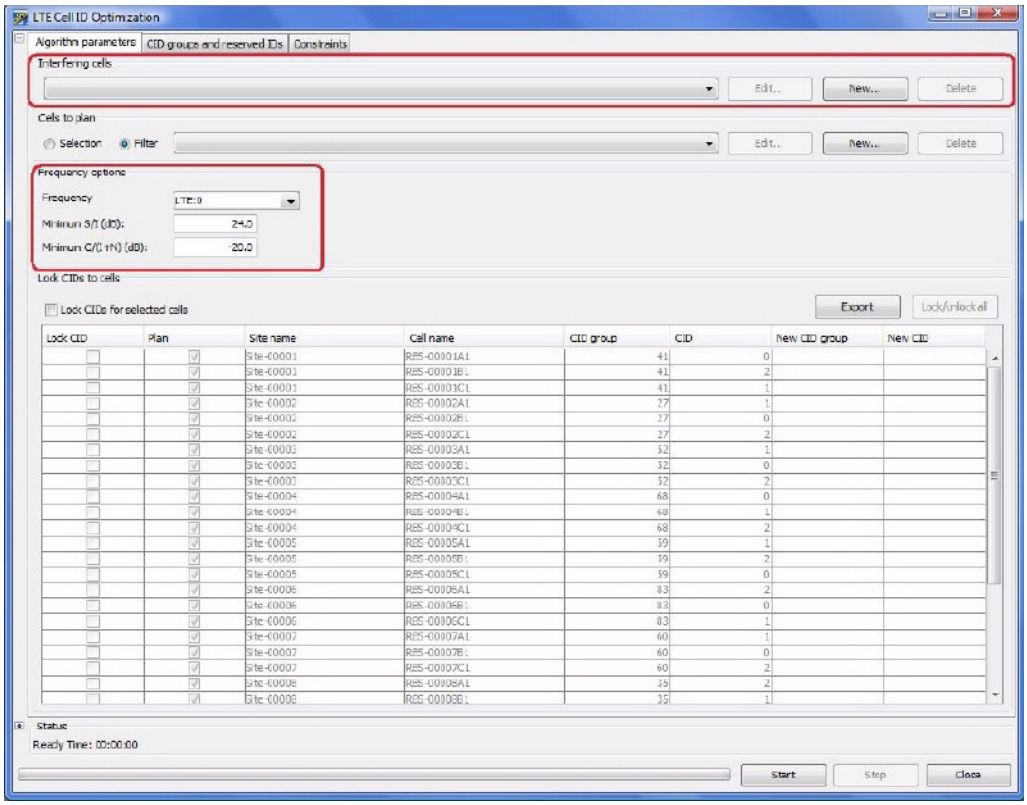
In detail, the interference cost is applied for each bin in the coverage area of the target cell (the cell that should get a Cell-ID assigned), in which a second cell and potential interferer is "visible". The visibility of an interfering cell is defined by the received Signal Strength from that cell (considered as interference I) in the best server coverage area of the target cell (considered as S).

If the Signal Strength from another cell exceeds the minimum S/I threshold as defined by the planner it will be considered an interfering cell and the interference cost applies for all bins in the best server coverage area, for which this statement is true. The setting of interference cost related parameters is done in the Algorithm Parameters editor of the Cell-ID Optimization window, see figure below.

This means, that the interference cost is scaled with the best server coverage area of the target cell. If a target cell with a large best server coverage area has the same Cell-ID as other (interfering) cells that are "visible" in many bins of the target cell, the cost for allocating this Cell-ID will be high.

The cost is calculated as one cost unit per square kilometer of overlap between the best server coverage area of the target cell and an interfering cell with the same ID.

There might be the case that certain cells contribute to the interference in the network and their Cell-ID should be considered when analyzing interference penalties during Cell-ID Optimization, but the actual Cell-ID of these interfering cells should not be included in the planning and optimization. Such situation might occur when an existing network is expanded or when a Cell-ID Optimization is done in a border area without influencing the Cell-ID plan of the LTE network on the same LTE



carrier frequency in the neighboring country. In such cases the network planner can include a list of "Interfering cells" in the Cell-ID Optimization. Observe, that the radio parameters for the interfering cells must be set in TEMS CellPlanner in order to include them in the Cell-ID Optimization.

4.2.4 Unlock Cost

The planner can lock already assigned Cell-IDs to cells and assign a certain unlock cost for that cell. This feature is valuable in cases of network expansions or border area planning, when a change of Cell-ID has an impact on the overall network plan.

The Cell-ID optimization algorithm might find a lower total cost of the Cell-ID allocation if the ID of a locked cell is changed. In such case the unlock cost is applied with the specified value. For each unlock event in the network the unlock cost is applied once, i.e. a locked Cell-ID can only be unlocked once.

4.2.5 Distance Cost

The distance cost is another event-based penalty. It is applied when the minimum re-use distance for the Cell-ID between two potentially mutual interfering cells is not observed.

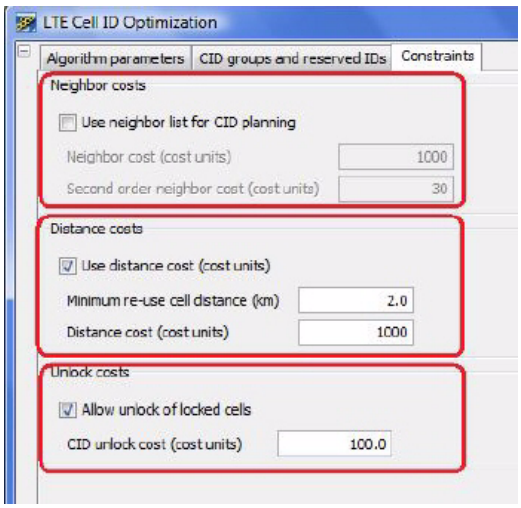
Note that the distance cost is applied once the distance threshold "Minimum reuse distance" is reached. There is no scaling of costs in relation to how much the distance threshold was violated.

4.2.6 Neighbor Cost

The neighbor cost is also an event-based penalty. It applies when the same Cell-ID is used for the target cell as for any of the first or second order neighbors. The neighbor information is retrieved from the neighbor list in TEMS CellPlanner. Therefore, it is important that the neighbor list reflects accurate information and is up to date with the actual cell plan before the Cell-ID Optimization is done.

Note: *Observe that during Cell-ID optimization all neighbor relations are considered as mutual, regardless of whether or not the cells are defined as mutual neighbors in the neighbor list.*

Setting of unlock, distance and neighbor cost parameters is done in the Constraints editor of the Cell-ID Optimization window, see figure below.



4.2.7 Export of Cell-ID Plan

The Cell-ID Plan can be saved in the network plan. In this case the new assigned Cell-ID is saved as a parameter of the cell attributes. In case a previously assigned Cell-ID was changed (from a locked or unlocked cell), the old Cell-ID is overwritten with the new ID.

The Cell-ID plan can be exported using the Export functions of TEMS CellPlanner. The Cell-ID plan can also be exported from the Generate report button to a Microsoft Excel spreadsheet for further processing.

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